In-Situ 3D Mapping of Cold Cap Utilizing X-Ray Computed Tomography

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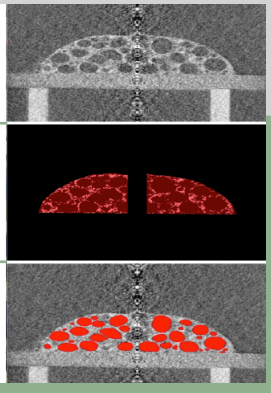

Top: Original x-ray CT image of the A19-Original feed pellet.

Middle: Following grayscale threshold segmentation.

Bottom: Following manual segmentation.

Technical Summary

In a high level nuclear waste (HLW) glass melter, the feed composition affects the overall throughput rate by influencing the thermophysical and morphological properties of the cold cap layer where the primary feed to glass conversions occur. At the base of the cold cap above the molten glass pool, an insulating foam layer forms that reduces the heat transfer to the upper portion of the cold cap. Data from X-ray computed tomography (CT) of surrogate waste feed pellets heated at a rate of 10°C/min provide insight into the relative melting rates of different feed formulations, along with distribution and morphology of bubbles that collectively form the foam. Within this layer, the various feed compositions react to form glass at temperatures between 600°C and 1040°C. The X-ray CT images can be digitally segmented to capture features of interest, then processed to determine the cross-sectional area and void fraction in a plane passing through the pellet mid-plane. These results can then be used to analyze the melting and foaming behavior of the waste glass as a function of H_3BO_3, $LiCO_3$, SiO_2, and Na_2CO_3 content and temperature. These temperature-dependent morphological data can be used in models of heat transfer within a HLW glass melter, with emphasis on nuclear waste vitrification operations at the Hanford Site in Washington, USA.

Path Forward

- Data from X-ray CT measurements acquired at the Tokyo Institute of Technology and provided to DOE are only 2D with limited resolution. For future studies, high resolution 3D data will be sought.
- Since the maximum bubble size is inherently limited by the size of the pellets used in the experiment, larger scale studies are needed to gain an accurate understanding of primary foam morphology at high temperatures.
- It is suggested that a more robust threshold segmentation method be developed, possibly including shape-based segmentation algorithms to identify near-spherical bubbles, to expedite the analysis.
- Plans for future studies include comparison of the 2D profiles with 3D volume data from X-ray CT measurements. The insights gained from these results can be used to synthetically generate a cold cap structure for use in heat transfer models of the cold cap layer.

Key Accomplishments

- X-ray CT was performed for six pellet compositions during heating from room temperature to melter operational temperatures.
- Images were analyzed at INL using morphological processing to extract quantitative information, including the size and shape of bubbles and the void fraction of primary foam.
- The data suggest that viscosity does not have a significant hindering effect on pellet expansion, but that the initial collapse temperature depends strongly on viscosity.
- A conference presentation and a journal article were prepared to disseminate the research results.

Key Benefits

- X-ray CT imaging was used to examine the waste glass feed during heating, providing its inner structure as a function of temperature. Morphological processing algorithms were then applied to this data to extract quantitative information from the images, including the size and shape of bubbles and the void fraction of primary foam.
- Previous pellet melting studies at PNNL have provided optical information on pellet deformation as a function of temperature, but it was not feasible to obtain data on the interior structure during melting. The X-ray CT method supplements and improves upon visual characterization of the melting feeds.
- Improved understanding of the pellet melting process could lead to increased melter throughput by allowing operation at conditions that permit increased waste loading and melter temperature.

For more information on this project or the EM International Program

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